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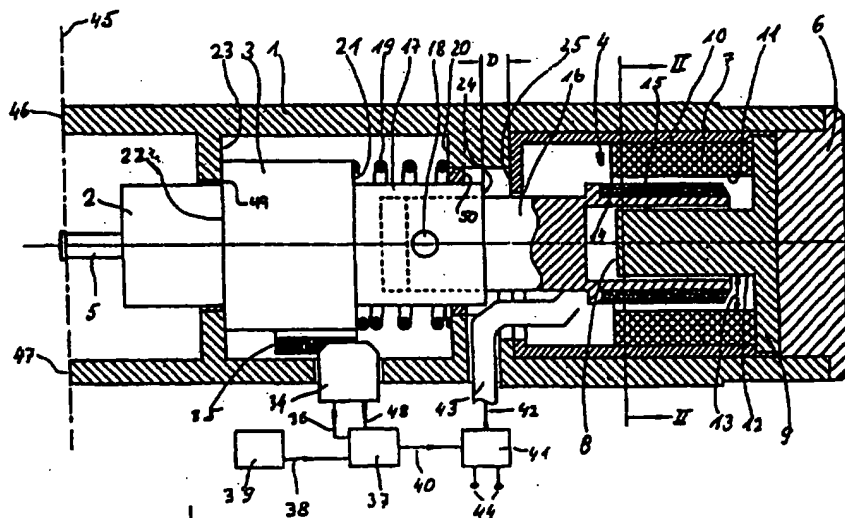
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<p>(21) International Application Number: <b>PCT/US95/14197</b> (22) International Filing Date: <b>18 October 1995 (18.10.95)</b> (30) Priority Data: P 44 37 264.7      18 October 1994 (18.10.94)      DE 08/335,551      7 November 1994 (07.11.94)      US (71) Applicant (for all designated States except US): <b>EMHART INC. [US/US]; Drummond Plaza Office Park, 1423 Kirkwood Highway, Newark, DE 19711 (US).</b> (72) Inventors; and (75) Inventors/Applicants (for US only): <b>CUMMINGS, Gerald, Floyd [CA/CA]; 3083 E. Kent Avenue N. #906, Vancouver, British Columbia (CA). MAUER, Dieter [DE/DE]; Ostendstrasse 10, D-6304 Lollar (DE).</b> (74) Agents: <b>MURPHY, Edward, D. et al.; The Black &amp; Decker Corporation, 701 E. Joppa Road, Towson, MD 21286 (US).</b></p>		<p>(81) Designated States: <b>AL, AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TT, UA, UG, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ, UG).</b>  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>

(54) Title: **STUD WELDING DEVICE**



(57) Abstract

Stud welding device with an axially displaceable adjusting element (3, 17) for displacement from a front position into a rear position and back, in which a magnetic field and a coil (15) interact in such a way that, when the coil (15) is connected to a controllable current source (41) an axial force is produced in order to displace the adjusting element (3, 17), the movement of which is transmitted to a stud holder (2), characterized in that the coil (15) is rigidly arranged on a hollow body (14) which is connected to the adjusting element (3, 17) and is arranged axially movably in an air gap (13) between a magnetizable core (8) and a magnetizable sheath (10), the magnetic field being conveyed via at least one yoke (9) connecting the core (8) and the sheath (10) while passing radially through the coil (15), the coil exerting on the adjusting element (3, 17) an axial force acting only in one direction as a function of the direction of current during current control.

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## *Stud Welding Device*

### *BACKGROUND OF THE INVENTION*

The invention relates to a stud welding device with  
10 an axially displaceable adjusting element for  
displacement from a front position into a rear position  
and back, in which a magnetic field and a coil interact  
in such a way that, when the coil is connected to a  
controllable current source an axial force is produced in  
15 order to displace the adjusting element, the movement of  
which is transmitted to a stud holder.

### *Description of the Prior Art*

20 A stud welding device of this type is known from US-  
PS 5,321,226. The operating principle on which this  
device is based is shown in Figure 5 thereof. With that  
device, a permanent magnet designed as a bar magnet is  
moved axially to and fro so as to form an adjusting  
25 element on which a stud holder is arranged so that a stud  
fixed in the stud holder is axially displaced during  
displacement of the adjusting element. This displacement  
is then used in the conventional manner for igniting an  
arc and welding the stud to the workpiece. The forces to  
30 be applied for displacing the bar magnet originate from  
two coils arranged axially one behind the other with  
opposing winding directions which form electromagnets of  
opposing polarity during the flow of current. The bar  
magnet can move axially along the coil axes, more  
35 specifically to a stop at the two respective outer ends  
of the coils.

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When the two coils are excited by the flow of electric current, the bar magnet which is prevented from moving outwardly by the stops is to move in the direction of the other coil by which it is initially repelled owing to the direction of the magnetic field produced by it. This repelling force has to be overcome by the coil which initially comprises the bar magnets so the bar magnet moves out of this coil and enters the other empty coil until it reaches the respective stop at its other end.

For the return movement of the bar magnet, the polarity of the flow of current then has to be reversed via the two coils connected in series. This magnetic system is obviously dependent on special balancing of the interacting magnetic fields, with the result that, during continued movement of the permanent magnet, the forces acting on it vary to a considerable extent. Once the repelling forces initially emanating from the empty coil have been overcome, the bar magnet, once it has entered the empty coil, is drawn into the empty coil with continuously increasing forces. This is a problem for controlled movement of the adjusting element at a specific speed at the respective individual positions of the stud, particularly if the stud is to be prevented from sinking into the melt produced by the arc at an excessively high speed.

The object of the invention is, while utilizing the magnetic principle mentioned at the outset, to design the stud welding device in such a way that at a given current

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5 strength which excites the coil, the axial force acting  
by the magnetic field on the adjusting element remains  
substantially equal independently of position.

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#### *SUMMARY OF THE INVENTION*

According to the invention this is achieved in that  
the coil is rigidly arranged on a hollow body which is  
connected to the adjusting element and is arranged  
15 axially movably in an air gap between a magnetizable core  
and a magnetizable sheath, the magnetic field being  
conveyed via at least one yoke connecting the core and  
the sheath while passing radially through the coil, the  
coil exerting on the adjusting element an axially force  
20 acting only in one direction as a function of the  
direction of current during current control.

With this design, the hollow body with the coil  
carried by it forms a relatively lightweight component.  
25 During its axial displacement at least in the range of  
movements during the welding process, it remains  
substantially in the radially extending magnetic field so  
the coil is exposed to a substantially steady axial force  
during the axial displacement of the coil while the  
30 current flowing via the coil is constant. The axial  
forces acting on the coil and therefore the hollow body  
with the adjusting element can therefore be calculated  
accurately for each position within the path of  
adjustment of the coil. This results in the significant

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5 advantage over the bar magnets which are axially  
displaced in the prior art that the components which are  
decisive for producing the axial forces, namely the coil  
and the hollow body carrying it, can be relatively light  
weight in construction. For example, the hollow body can  
10 consist of a light plastics material. On the other hand,  
the bar magnet according to the prior art has a  
considerable mass if it is to produce a magnetic field of  
significant intensity at all. This mass counteracts the  
accelerations which are required for the adjusting  
15 movement of the adjusting element and then have to be  
produced by correspondingly high currents through the two  
coils connected in series. On the other hand, higher  
accelerations and decelerations can easily be achieved  
with the design according to the invention owing to its  
20 relatively low mass.

The accuracy of adjustment of the adjusting element  
can be increased by designing the device in such a way  
that a spring which presses the adjusting element into an  
25 end position defined by a stop acts upon the adjusting  
element. If the spring acts against the axial force  
applied by the coil, the axial force has to overcome the  
spring force so the adjusting element is lifted from its  
stop. The axial force required can be adjusted very  
30 accurately by adjustment of a corresponding current  
flowing via the coil, and the increasing spring force of  
the spring can also be taken into consideration during  
compression of the spring. Conversely, it is possible to  
ensure by means of an appropriate axial force that the

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5 adjusting element moves back to the stop if the spring force is greater than the axial force.

The magnetic field required for producing the axial force can be applied by a permanent magnet, but it is  
10 also possible to provide an electromagnet for this purpose.

If a permanent magnet is used, it is preferably integrated into the casing of the stud welding device.  
15 If an electromagnet is used, it can be placed in the connection between core and yoke.

If the adjusting element is to be moved in accordance with a predetermined pattern of movement, the  
20 stud welding device is preferably designed such that it is provided with a linear displacement measuring device from which there can be derived a displacement signal which corresponds to the respective relative position of casing and adjusting element and, as an actual value, is  
25 compared stepwise in a comparator with a desired value from a predetermined displacement-time graph for the movement of the stud holder read stepwise from a memory, the comparison signal of the comparator controlling the current intensity of a current source for supplying the  
30 coil.

A control process is carried out by comparing the actual signal with the stored desired signal using the displacement measuring device and the comparator, this

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5 control process ensuring that the displacement signal  
derived from the displacement measuring device is  
invariably opposed by the corresponding datum from the  
displacement-time graph so the sequence of movement  
corresponding to the displacement-time graph may be  
10 maintained with great accuracy during the movement of the  
adjusting element. In particular, this allows a rapid  
stud lifting movement and a correspondingly rapid return  
of the stud with an adequate interval for the melting of  
the material at the weld, it additionally being possible  
15 to design the return movement of the stud into the melt  
at the end such that the weld stud sinks into the melt at  
a desired speed, in particular preventing the molten  
material from being sprayed away during impingement of  
the weld stud, this frequently occurring when a spring is  
20 used alone to produce the return force of a weld stud.

The storage of the displacement-time graph in the  
memory also permits different displacement-time graphs to  
be provided as a function of the workpieces to be welded  
25 in each case, and these displacement-time graphs can be  
called up selectively during operation of the stud  
welding device.

The adjusting element including the stud holder is  
30 preferably pressed by the spring into its forward  
position relative to the stud welding device. From this  
position, the adjusting element is displaced, during  
application of a stud held by the stud holder onto a  
workpiece, into a reference position which is supplied



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5 from the displacement measuring device as a reference  
signal to the comparator from which the predetermined  
displacement-time graph is derived. Owing to this  
reference position, which automatically arises during  
application of the stud onto a workpiece, the  
10 respectively predetermined displacement-time graph can be  
derived without orientation of the stud relative to the  
stud welding device, the respectively adopted reference  
position automatically forming the starting position for  
the movement of the stud. With the application of the  
15 stud, the stud welding device is automatically orientated  
with respect to its height relative to the workpiece  
without a special manipulation being required for this  
purpose.

20 Another problem in conventional stud welders such as  
those which use solenoids to control the back and forth  
movement of the welding gun from a retracted position to  
an operative position in which the stud is juxtaposed to  
a metal part to which it is to be welded in the need to  
25 adjust for each different type of weld. Because the  
stroke of conventional drives is often short, because the  
position of the workpiece to which welding must be  
accomplished varies over a range larger than the stroke,  
and because the amount which the stud "sticks out" from  
30 the welding head varies, it can be difficult to  
accommodate these variations in a smooth, high speed  
operation. The reliability of welders could be improved  
and their expense reduced by using an actuator with a

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5 long stroke. Typically, a suitably long stroke would be about 10 mm.

One object of this invention is, accordingly, the provision of an improved magnetically driven stud welding  
10 device which is capable of smooth, high speed operation over a long stroke path. The object is achieved by the structure of this invention.

The invention is described in detail hereinafter  
15 with reference to a specific embodiment illustrated in the accompanying drawings in which:

*BRIEF DESCRIPTION OF THE DRAWING*

20

FIGURE 1 shows the stud welding gun equipped with a permanent magnet with the stud holder in its forward position;

25 FIGURE 2 is a section through the arrangement according to FIGURE 1 along line II-II;

FIGURE 3 shows the magnetic part of the stud welding gun according to FIGURE 1 but with an electromagnet, the  
30 adjusting element being shown in a rear position; and

FIGURE 4 is a displacement-time graph which is plotted as a range of movement and in which the movement of a weld

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5 stud has to take place while allowing for a given  
workpiece.

*DESCRIPTION OF THE PREFERRED EMBODIMENT*

10 FIGURE 1 shows a stud welding device with a casing  
1, a stud holder 2, an axially movable adjusting element  
3 and a magnet system 4. A weld stud 5 which is to be  
welded to a workpiece (not shown) is fixed in the stud  
holder 2. The casing 1 encloses the stud holder 2, the  
15 adjusting element 3 and the magnet system 4 and is closed  
at its end remote from the stud holder 2 by the rear wall  
6.

The magnet system 4 responsible for the movement of  
20 the stud holder 2 consists of the permanent magnet 7, the  
core 8 and the yoke 9 which adjoins the core 8 and closes  
the magnetic flux originating from the permanent magnet  
7. The material of the permanent magnet is samarium  
cobalt or neodymium boron iron which provides a  
25 relatively large magnetic field in response to a given  
magnetizing force in comparison to conventional  
materials. At its exterior, the permanent magnet 7 is  
surrounded by the casing 10 which consists of  
magnetically conductive material and supplies the flux  
30 conveyed via the yoke 9 to the rear of the permanent  
magnet 7. Between the internal face 11 of the permanent  
magnet 7 and the external face 12 of the core 8 there  
exists the air gap 13 in which the sleeve 14 with the  
coil 15 wound thereon is axially movably arranged. The

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5 magnetic field bridging the air gap 13 therefore passes  
through the coil 15 so the coil 15 is exposed to an axial  
force as current flows through the coil 15. This axial  
force is dependent on the one hand on the intensity of  
the magnetic field and on the other hand on the intensity  
10 of the current flowing through the coil 15, resulting in  
a corresponding axial displacement of the coil 15 and  
therefore of the sleeve 14 during the flow of current  
while allowing for the inertia of the components  
connected to the coil 15. The sleeve consists of  
15 magnetically non-conductive material, for example of a  
rigid plastics material, so it cannot influence the  
magnetic field passing through the coil 15.

The extension 16 adjoins the sleeve 14 in the  
20 direction of the weld stud 5 and continues into the  
length of tube 17 forming part of the adjusting element  
3. The extension 16 is connected to the length of tube  
17 by means of the pin 18 penetrating these two  
components. A non-positive connection of sleeve 14 is  
25 produced in this way via the extension 16 to the length  
of tube 17 and therefore the adjusting element 3 on which  
the stud holder 2 is fastened. Owing to a rigid  
connection between the coil 15 and the sleeve 14, axial  
forces originating from the coil 15 owing to the magnetic  
30 field act directly on the sleeve 14 so an axial movement  
of the coil 15 is transmitted in its entirety to the weld  
stud 5.

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5           The movable adjusting element 3 is supported by  
bushings as shown at 49, 50. Bushings 49, 50 are  
preferably made of Frelon, a composite bearing material  
including a polytetrafluoroethylene compound which is  
available from the Pacific Bearing Seal Co. of Rockford,  
10 IL, which has been found to withstand the large number of  
abrasive particulates and ions that are present in a  
welding environment and cause most known materials to  
fail in a very short time. Frelon provides an  
unexpectedly low friction with element 3 and to have any  
15 unexpectedly long life even in the extremely adverse  
environment of a welding gun.

          The length of tube 17 carries the helical spring 19  
resting on the one hand on an internal projection 20 of  
20 the casing 1 and on the other hand on a shoulder 21 of  
the adjusting element 3. The helical spring 19 presses  
the adjusting element 3 with its front face 22 against  
the internal shoulder 23 of the casing 1, the internal  
shoulder 23 forming a stop on attainment of which the  
25 adjusting element 3 adopts its front end position.

          Against the tension of the helical spring 19, the  
adjusting element 3 and therefore all other components  
connected to it can be displaced axially into a rear end  
30 position which is defined by the end face 24 running  
against the front wall 25 of the casing 10. In order to  
bring the length of tube 17 and therefore the weld stud 5  
and the coil 15 into this rear end position, a  
correspondingly high current has to be applied to the

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5. coil 15 to produce an axial force which overcomes the opposing force of the helical spring 19. The range of adjustment of the adjusting element 3/17 corresponds to the distance D.

10       The above-described components of the stud welding device are essentially rotationally symmetric bodies, as shown in Figure 2 which is a section along line II-II in Figure 1.

15       Figure 3 essentially shows the magnetic part of the stud welding device according to Figure 1, but an electromagnet 26 which consists of a winding and applies the magnetic field required for the necessary axial movement is provided in the magnet system 4. The  
20       winding of the electromagnet 26 is wound onto the core 27 so the magnetic field originating from the electromagnet 26 spreads via the core 27 to the yoke 28 from where it is conveyed via the casing 10 and the bush 29 inserted therein to the coil 15. As in the embodiment according  
25       to Figure 1, the coil 15 is wound onto the sleeve 14 which continues to the left into the extension 16. Casing 10 and bush 29 consists of magnetizable material. As in the embodiment according to Figure 1, the entire arrangement is enclosed by the casing 1. The components  
30       which are connected on the left are the same as in the embodiment according to Figure 1, so reference can be made to the description of Figure 1 in this respect.

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5           Figure 3 shows the sleeve 14 in its rear end  
position. In this end position, the coil 15 is kept  
under the influence of the magnetic field of the  
electromagnet 26 of which the magnetic field bridges the  
air gap 13 between the external surface of the core 27  
10 and the internal surface of the bush 29. A magnetic flux  
which passes radially through this air gap and to which  
the coil 15 arranged axially movably in the air gap 13 is  
fully exposed is therefore produced as in the embodiment  
according to Figure 1.

15

Movements at accurately maintained speeds along the  
path covered can be achieved within a period of up to 1  
second required for the entire welding process using the  
stud welding devices shown in Figures 1 and 3. During  
20 these movements it is important to utilize a pilot  
current which is switched on when the weld stud makes  
contact with the workpiece to ignite a pilot arc which  
burns after the pilot current has been switched on owing  
to removal of the weld stud from the workpiece, then to  
25 produce a melt on the workpiece by means of the welding  
arc which is also switched on while holding the weld stud  
in a rear end position, whereupon the weld stud is moved  
beyond the previously adopted starting position in the  
direction of the workpiece, the weld stud sinking with  
30 its end face into the melt which then solidifies. Owing  
to the melt, the weld stud adopts a position which is  
advanced slightly further than the starting position and  
into which it is moved at a relatively low speed so that  
the spraying of liquid metal owing to an abrupt entrance

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5 of the weld stud into the melt is prevented. Depending  
on the welding parameters (strength of the workpiece,  
thickness of the weld stud, workpiece material and the  
like) there are various patterns of motion for this  
sequence of movements which have to be observed in order  
10 to achieve optimum welds.

A range of movement comprising such a pattern of  
motion is plotted as a graph in Figure 4. The respective  
position L of the weld stud with respect to a starting  
15 position 0 is plotted on the abscissa of the graph. The  
ordinate represents a time axis for the lapsed time t.  
In the graph, the individual points therefore represent  
the position L of the weld stud at a specific moment  $t_x$ .  
The hatched field represents the limit values for  
20 patterns of motion extending within this field. It  
starts from the starting position 0 and passes via the  
lines 30 and 31, reaching the end positions L1 and L2 in  
which the weld stud remains in its position between  
moments  $t_1$  and  $t_2$ . The oblique position of the lines 30  
25 and 31 represents the speed of the weld stud in its  
movement. After moment  $t_2$ , the weld stud is moved along  
lines 32 and 33 back in the direction of the workpiece  
where, after passing beyond the line 0 defining the  
starting position, sinks into the melt at a decreasing  
30 speed. The weld stud passes through the region from the  
line 0 to the line  $L_3$ , on attainment of which the weld  
stud has reached its end position after passing through  
the return movement. As shown, the lines 32 and 33  
extend in the region between level 0 and  $L_3$  with a



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5 constantly decreasing inclination, representing the decreasing speed.

Optimum welding of the respective weld stud is produced if the pattern of motion which is observed  
10 exactly during this movement lies in the hatched region according to Figure 4.

The automatic resetting arrangement shown in Figure 1 is provided in order to control the stud welding device  
15 in the sense of a pattern of motion described in conjunction with Figure 4. This resetting arrangement is based on the absolute measurement of the respective position of the adjusting element 3 and therefore of the weld stud 5 by means of the linear displacement measuring  
20 device 34 which scans a scale 35 arranged on the adjusting element 3 and produces a corresponding displacement signal depending on the determined position of the adjusting element 3. This displacement signal is supplied via the line 36 to the comparator 37 which also  
25 receives stepwise, via the line 38 from the memory 39, position signals which represent a desired signal for the weld stud 5 in the sense of a pattern of motion contained in the memory 39. This desired signal, as an actual signal, is compared with the displacement signals  
30 transmitted via the line 36 and the result of comparison is conveyed via the line 40 to the controller 41 which adjusts the current strength of the current supplied to the coil 15 via the line 42. The line 42 is continued in the channel 43 shown as a pipe and is attached to the

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5 ends of the coil 15. The controller 41 receives, at its terminals 44, a voltage which is then adjusted on the basis of the comparison signal supplied via the line 40.

In detail, the following operations take place: one  
10 or more displacement-time graphs are stored in the memory 39 as laws of motion which can be called up selectively so the individual positions of the weld stud 5 at associated moments can be fed to the comparator 37 stepwise via the line 38. The comparator 37 compares  
15 these individual desired signals which are offered stepwise with the actual signals which are supplied via the line 36 and indicate the actual position of the weld stud 5. In the event of a deviation in the signals supplied to the comparator 37, the comparator 37 delivers  
20 a control voltage which is transmitted via the line 40 and of which the value and sign are controlled in a known manner by the controller 41 in such a way that the coil is supplied with either a stronger or a weaker current to be able to come as close as possible to the desired  
25 position of the weld stud 5. This process takes place stepwise according to the shape of the pattern of motion from the memory 39, the coil 15, and therefore the mechanism connected to it in its entirety, being forcibly moved. In particular, it is possible to adjust the  
30 respective speed of the coil 15 in the manner required for the respective phase in the course of the welding process. In particular, the return movement from the rear end position in the direction of the workpiece can therefore be delayed during the immersion of the weld

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5 stud 5 into the melt, for which purpose the coil 15 may have to receive a current running in the reverse direction from before in order to decelerate the movement of the coil 15.

10 With this arrangement it is advantageously possible automatically to give the weld stud 5 a reference position during application of the stud welding device to a flat workpiece. This is effected by pressing the stud welding device according to Figure 1 against a flat  
15 workpiece, the weld stud 5 projecting beyond the dot-dash connecting line 45 being pressed back against the pressure of the helical spring 19. The dot dash line 45 represents a plane connecting the end faces 46 and 47 of the casing 1. When the end faces 46 and 47 are applied  
20 to a flat workpiece, a defined position is produced with respect to the weld stud 5, this defined position giving the weld stud its reference position, as stated. This reference position is read from the scale 35 by means of the displacement measuring device 34 and is transmitted  
25 to the comparator 37 as a reference signal via the line 48. The comparator 37 therefore begins to operate on the basis of the reference signal as actual signal in comparison with the desired signal which is read from the memory 39 and must remain equal at the beginning of the  
30 welding process while the weld stud 5 remains in the adopted position. The pattern of motion is then covered in the above described manner, the actual signal supplied to the comparator 37 via the line 36 being included stepwise.

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It is not necessary for the workpiece to have a plane configuration. Even if the workpiece has curves in the region of the welding process, it is still possible to displace the weld stud 5 into its respective reference position in which the weld stud contacts the workpiece. This is its reference position from which the welding process takes place in the conventional manner.

Utilizing a moving coil rather than a movable permanent magnet and selecting the magnet material to be a rare earth material such as samarium cobalt or neodymium boron iron, one can achieve speeds of up to 800 millimeters/second and coil strokes of over 5 mm. Coil strokes of up to 10 mm have been achieved. Such long strokes allow the position of the actuator to be adjusted to compensate for the variation in distance to the workpiece from the end of a stud. Faster response and more accurate position control of the coil are achieved by using a moving coil which has a much lower mass than the permanent magnet. Moreover, the tendency of moving permanent magnets to pull towards one side due to its attraction to nearby metal, known as off-axis side loading, results in excessive wear on the bearings and premature failure. Such an effect is avoided by using a moving coil.

Another advantage of the moving coil is the avoidance of the hysteresis present in moving permanent magnet actuators. Since the permanent magnet is

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5 surrounded by steel parts the amount of current required  
to move the permanent magnet at a given position will  
depend upon whether it is moving from the left or the  
right. No such effect can occur with a moving coil.  
Thus, the moving coil system allows for simpler and more  
10 accurate position control than does a moving permanent  
magnet and fixed coil system.

Accordingly, while this invention has been described  
with reference to illustrative embodiments, this  
15 description is not intended to be construed in as  
limiting sense. Various modifications of the  
illustrative embodiments, as well as other embodiments of  
the invention, will be apparent to persons skilled in the  
art upon reference to this description. It is therefore  
20 contemplated that the appended claims will cover any such  
modifications or embodiments as fall within the true  
scope of the invention.

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CLAIMS

1. Stud welding device with an axially displaceable  
adjusting element (3, 17) for displacement from a front  
position into a rear position and back, in which a  
10 magnetic field and a coil (15) interact in such a way  
that, when the coil (15) is connected to a controllable  
current source (41) an axial force is produced in order  
to displace the adjusting element (3, 17), the movement  
of which is transmitted to a stud holder (2),  
15 characterized in that the coil (15) is rigidly arranged  
on a hollow body (14) which is connected to the adjusting  
element (3, 17) and is arranged axially movably in an air  
gap (13) between a magnetizable core (8) and a  
magnetizable sheath (10), the magnetic field being  
20 conveyed via at least one yoke (9) connecting the core  
(8) and the sheath (10) while passing radially through  
the coil (15), the coil exerting on the adjusting element  
(3, 17) an axial force acting only in one direction as a  
function of the direction of current during current  
25 control.

2. Stud welding device according to claim 1,  
characterized in that a spring (19) acts on the adjusting  
element (3, 17), pressing the adjusting element (3, 17)  
30 into an end position defined by a stop (23).

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5 3. Stud welding device according to claim 1  
characterized in that the magnetic field is applied by a  
permanent magnet (7):

4. Stud welding device according to claim 3,  
10 characterized in that the permanent magnet (7) is  
integrated into the sheath (10).

5. Stud welding device according to claim 1,  
characterized in that the magnetic field is applied by an  
15 electromagnet (26).

6. Stud welding device according to claim 5,  
characterized in that the electromagnet (26) forms the  
connection between core (27) and yoke (28).

20

7. Stud welding device according to claim 1,  
characterized in that it is provided with a linear  
displacement measuring device (35) from which a  
displacement signal corresponding to the respective  
25 relative position of sheath (10) and adjusting element  
(3, 17) can be derived, this displacement signal as  
actual signal being compared stepwise in a comparator  
(37) with a desired signal from a predetermined  
displacement-time graph (law of movement) read stepwise

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5 from a memory (39) for the movement of the stud holder  
(2), the comparison signal of the comparator (37)  
controlling the current strength of a current source (41)  
for supplying the coil (15).

10 8. Stud welding device according to claim 7,  
characterized in that various displacement-time graphs  
allocated to associated workpieces to be welded are  
stored in the memory (39).

15 9. Stud welding device according to claim 2,  
characterized in that the adjusting element (3; 17) is  
pressed by the spring (19) into its front position from  
which it is displaced during application of a stud (5)  
held by the stud holder (2) onto a workpiece into a  
20 reference position which is supplied as a reference  
signal from a displacement measuring device (35) to a  
comparator (37) from which the predetermined  
displacement-time graph is derived.

25 10. A stud welder comprising:

(a) a welding head having a stud receiving and  
retaining mechanism for holding an end of a stud towards  
a workpiece;



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5           (b) a linear actuator having a fixed permanent magnet, a movable coil coupled to an actuator shaft and said actuator shaft coupled to said welding head; and

          (c) a controller coupled to said actuator coil and to said welding head and operative to move said actuator  
10 coil and welding head from a retracted to an extended position and back again and to cause welding current to flow into said welding head.

11. A stud welder according to claim 10, wherein said  
15 permanent magnet is a rare earth material.

12. A stud welder according to claim 10, wherein said permanent magnet is selected from the group consisting of samarium cobalt and neodymium boron iron.

20

13. A stud welder according to claim 10, wherein said coil moves with a speed of up to 800 millimeters/second.

14. A stud welder according to claim 10, wherein the  
25 stroke of said coil is greater than 5 mm.

15. A stud welder according to claim 10, wherein said stroke is 10 mm.

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16. A stud welder according to claim 10, including a linear encoder for monitoring the position of the actuator shaft.

10 17. A stud welder according to claim 1, including a host computer coupled to said controller and wherein said host computer and controller are programmed to control said actuator and welding head so that current into said welder is caused to flow after said welding head has  
15 positioned a stud adjacent a workpiece and said stud is quickly moved to contact the workpiece after an end of said stud has been mailed.

18. A stud welder according to claim 10, wherein said  
20 actuator has a bushing made of Frelon.

19. A stud welder according to claim 10, including a disc spring having a central aperture engaging said actuator and outer bearing areas locked in place by a  
25 support.

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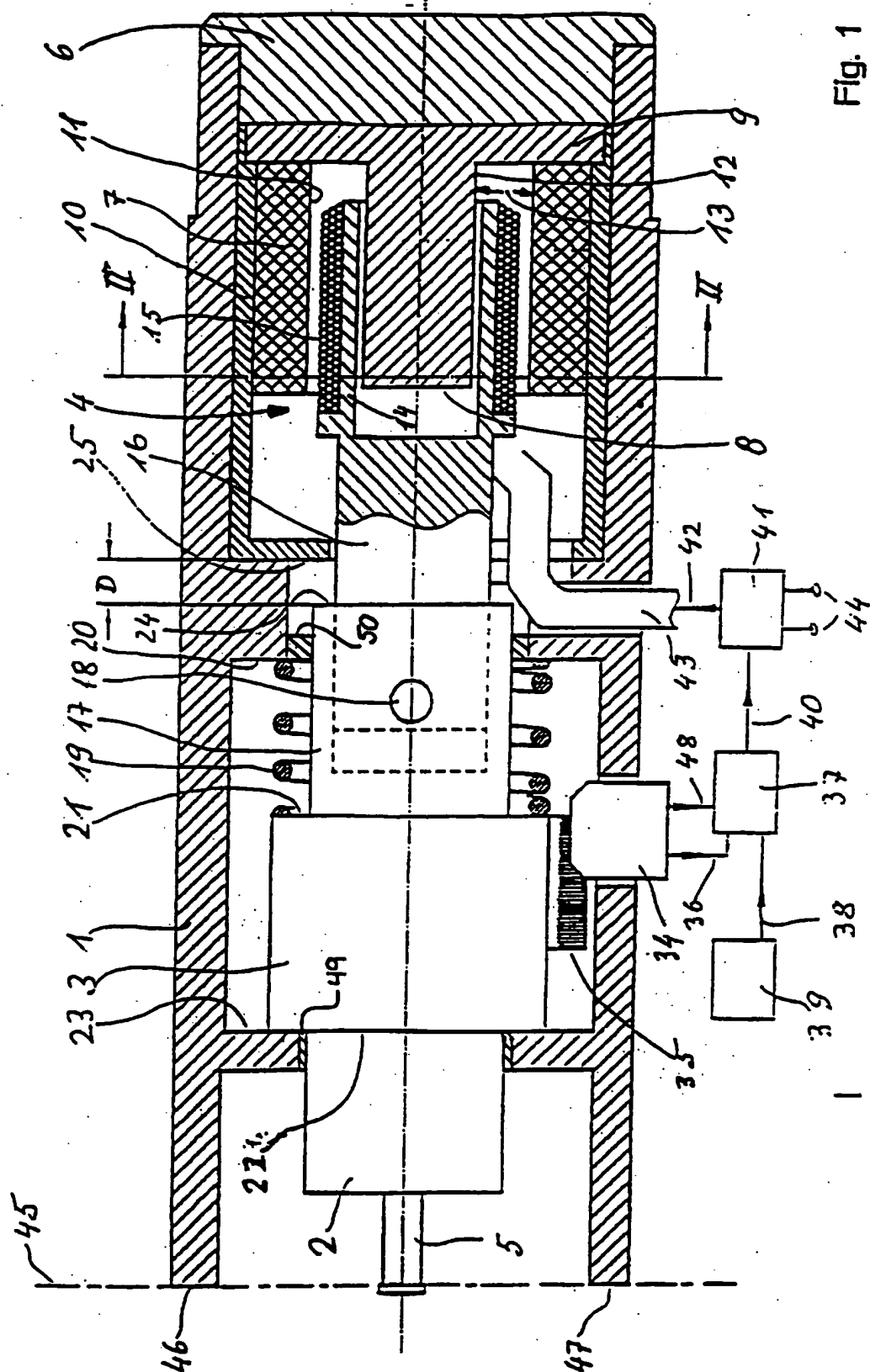


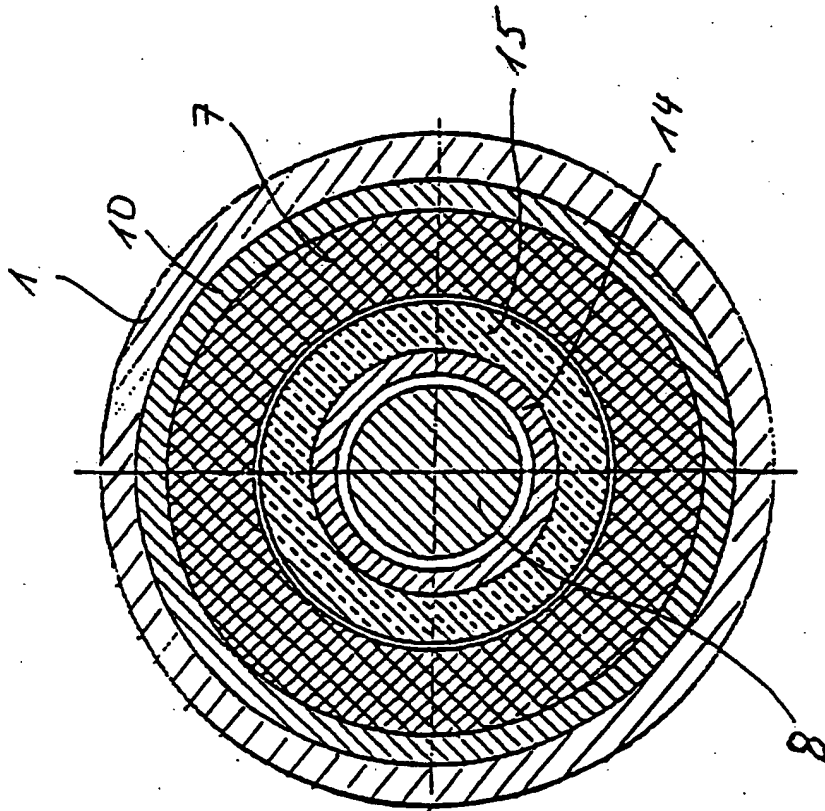
Fig. 1

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Fig. 2



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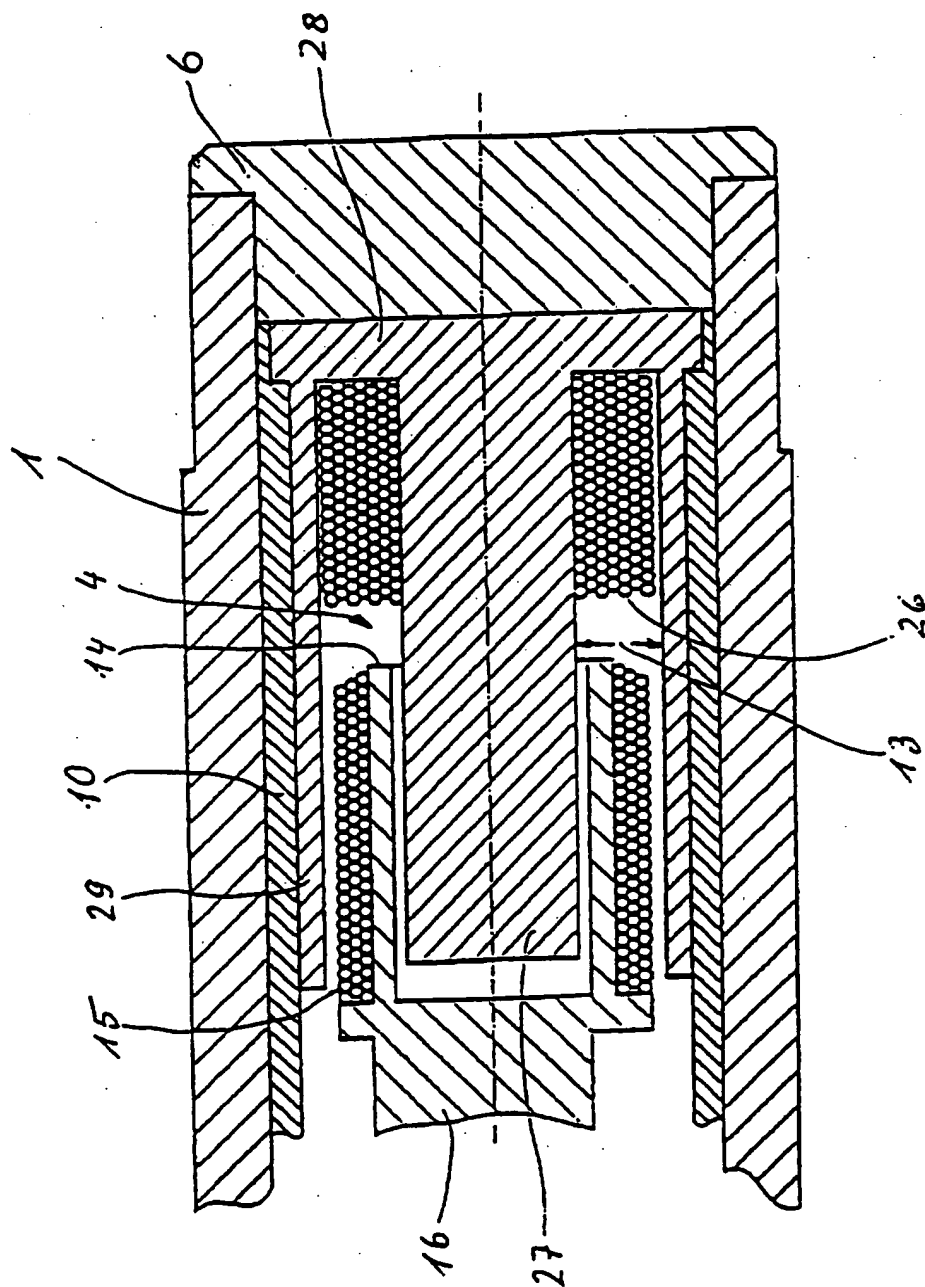


Fig. 3

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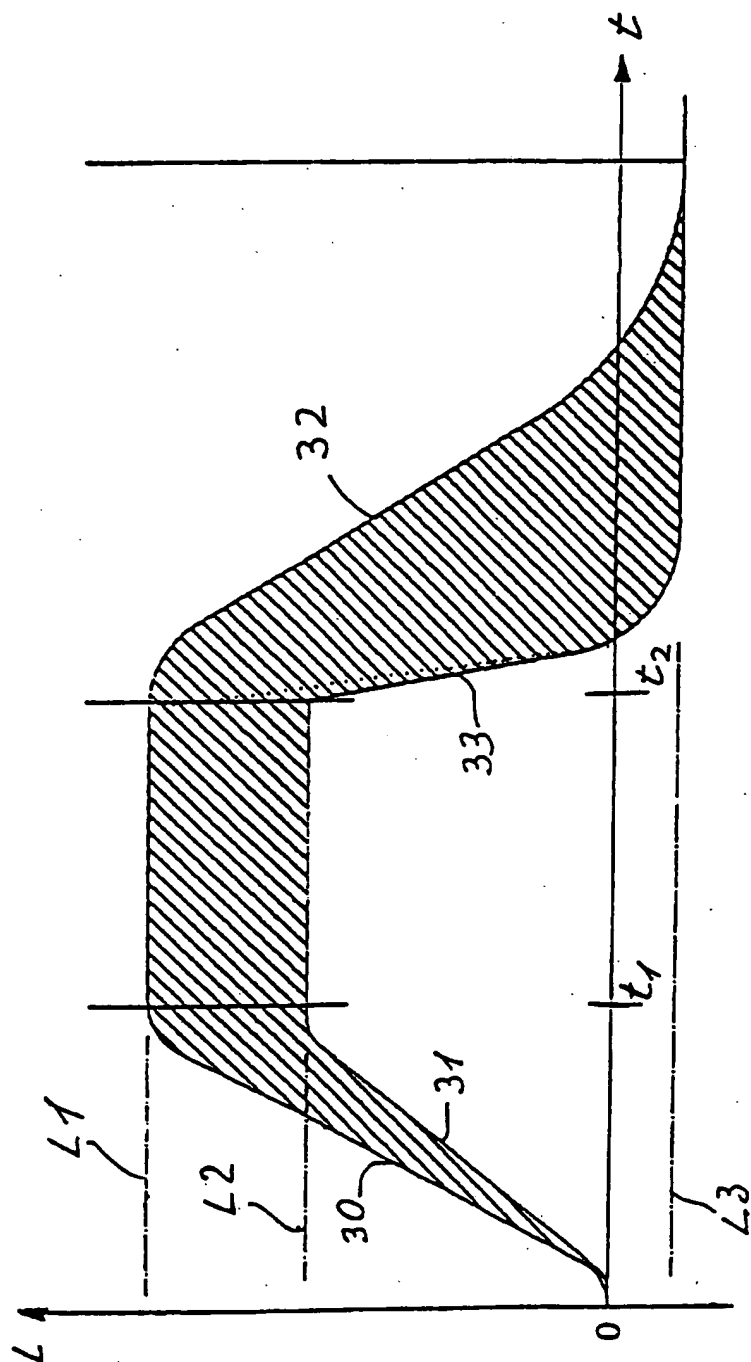


Fig. 4

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US95/14197

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B23K 9/20

US CL :219/98

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 219/98, 99

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,465,917 (HEIDER) 14 August 1984, see entire document.	1-19
A	US, A 5,252,802 (RAYCHER) 12 October 1993, see entire document.	1-19
A	US, A, 5,321,226 (RAYCHER) 14 June 1994, see entire document.	1-19
A	GB, A, 584,695 (SALTHOUSE) 21 January 1947, see entire document.	1-19

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	X	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	A	document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means		
*P* document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

16 FEBRUARY 1996

Date of mailing of the international search report

27 FEB 1996

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